Effects of Microgravity on the Formation of Aerogels

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Recently, we initiated a study of the microstructural formation process of the alcogel precursor of aerogel under gravity and microgravity conditions. This comparison will elucidate the effects of microgravity on aerogel porosity and microstructure. Understanding the processes that control the pore structure of silica aerogels will lead to better pore size control that can be used to improve the properties of aerogel. Aerogels are microstructured, open-pore materials with many unusual properties including: transparency, high thermal resistance, very low refractive index and sound velocity, and high surface area. Aerogel is synthesized using sol-gel processing followed by supercritical solvent extraction that leaves the original gel structure virtually intact.

Investigation of the role of gravity in materials processing must be undertaken through the study of well-mastered systems. Sol-gel processed materials are near-perfect candidates to determine the effect of gravity on the formation and growth of a lattice from aggregated units. Supercritical drying provides the method to preserve the sol-gel produced alcogel structure for study.

The presence of uncontrolled microporosity in aerogel leads to material non-uniformity that cause increased light scattering in aerogel. Knowledge of the effect of gravity driven solute flows and their effect on settling and agglomeration will enable us to improve preparation and properties of aerogel. Increased image clarity and decreased Rayleigh scattering from the pores of aerogel will significantly improve the prospects for large-scale adoption of aerogel in such applications as insulated windows, catalysts, gas separation media, and Cherenkov counters.

As in similar solution-growth systems, the growth of aggregates in sol gel systems is affected by density-gradient driven solutal flows, flows due to reaction-generated temperature gradients, and gravity-driven sedimentation. Research is underway on the effects of microgravity that will clarify the role of these flows and forces in the formation of aerogel and be compared with results of earthbound research. Determining the effects of reduced gravity prior to and during gellation will improve our knowledge of the sol-gel transition and suggest approaches to produce more uniform gels and aerogels.

We are engaged in this study of the role of gravity on pore structure and gel uniformity in conjunction with Marshall Space Flight Center (MSFC) on gelling systems during Shuttle flights. An apparatus constructed in an earlier project for microgravity platforms will be improved to monitor the gellation process and produce gels that can be characterized in detail after the flight. Laser light scattering will be used to probe the rate of gel growth under varying gravity conditions. The structure "frozen into" the gel during microgravity can be preserved by supercritical drying. The material is examined intensively using pore size distribution measurements, angular light scattering, spectral transmission measurements, and its uniformity determined by Schlieren and holographic methods. We will report on the proposed work as well as the result of research into methods of using ultraviolet radiation to initiate gelation instead of conventional catalysts. This approach was developed to study the effect of controlling catalysis in microgravity conditions. It offers a unique ability to turn the gelation process on and off. The effects of the UV stimulus were studied using light scattering techniques. Plots of the log of the scattering intensity vs. the log of time reveal two distinct slopes corresponding to cluster or chain aggregation of the primary silica particles in the sol and gel. It was found that the aggregation mechanism could be changed by removing the UV stimulus at various points the gellation process.

Increased comprehension of gel formation processes will benefit the broad understanding of sol-gel chemistry. In particular, the clarification of gel aggregation processes will help settle controversy over which of the various models of gel formation is correct. Thus, this research will advance both practical applications and fundamental science. Aerogel is being developed for a range of applications in the commercial and aerospace arenas. Thus improvements in processing gained through microgravity research can be used to produce better products that utilize aerogel.